

FROM: G. M. Yanizeski

**CENTRAL FILES
EXTRA COPY**

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D. C. 20024

SUBJECT: AAP CM-SM Thermal Control Systems
Case 620

DATE: November 4, 1968

FROM: G. M. Yanizeski

MEMORANDUM FOR FILEI. INTRODUCTION

The purpose of this memorandum is to provide an overall description of the thermal control systems employed on the AAP Command Module and Service Module (CM-SM) and to outline various problems and changes associated with the present configuration. The description serves to aid in understanding basically how CM-SM thermal control is attained; available numerical data are included for descriptive purposes. Analysis and design techniques are generally omitted since hardware is the major concern.

Although the final design of the CM-SM thermal control systems has not been determined, the Preliminary Requirements Review has been conducted and North American Rockwell, the prime contractor for the CM-SM, is preparing for the Preliminary Design Review in the early part of 1969. In addition, Martin Marietta and McDonnell Douglas have recently completed separate modification studies of the CM-SM. Information for this memorandum has been obtained from reports issued by these contractors, from NASA documents, and from conversations with various individuals concerned with CM-SM thermal control. As presented, this information reflects the current system configuration while indicating potential areas of change leading to the final system configuration.

In Part II of this memorandum, the general requirements for thermal control of the CM-SM are presented. The various AAP thermal environments are outlined, and comparisons with the Apollo Block II requirements are made.

In Part III, the AAP thermal control system is described along with the currently designated modifications to the Apollo Block II hardware (See Table I for a change summary). Passive thermal controls associated with the CM-SM outer structure are presented first, since they exert a general influence over the thermal control of various elements located within the CM-SM. At the same time, the overall CM-SM configuration is outlined. Next, the passive and active thermal controls more directly applied to specific systems and components located in the SM are described. And finally, those controls applied to elements located in the CM are similarly described.

II. REQUIREMENTS*

A variety of thermal environments exists for the AAP missions, both natural and induced:

1. The CM-SM with the crew is exposed to the earth atmosphere environment during prelaunch operations.
2. Substantial aerothermodynamic heat loads occur during boost and entry.
3. Both radiation and conduction heat loads are imposed by RCS and SPS firing events.
4. The CM-SM is subjected to a low earth orbit thermal environment, which lasts up to 56 days.

The Apollo CM-SM is designed for a lunar mission which requires occasional attitude holds. Temperature differences are controlled by barbecue rolling. In contrast, the AAP Earth orbital missions require fixed attitudes. In AAP 1-2 and 3A, the Orbital Assembly (OA) is perpendicular to the orbital plane with the solar arrays continually sun directed. In AAP 3-4, the longitudinal axis of the OA is maintained perpendicular to the solar vector again with the solar arrays continually sun directed. In AAP 3-4 alternate, the CM-SM, aligned with the solar vector behind the Lunar Module and Apollo Telescope Mount, is almost completely shadowed. This is the coldest mission.

Aside from these fixed attitude requirements, the significant difference between the two missions is that the AAP missions are cold-biased compared to Apollo. There is less internal heat generation in the CM due to the AAP power-down operation and the lower CM metabolic loads, and there is less external heating due to the earth orbital environment and cluster shadowing during the alternate mission. As a comparison, the net AAP Environmental Control System (ECS) heat rejection needs are 1,500 to 6,000 BTU/hr versus 4,940 to 8,570 BTU/hr for Apollo. Many of the changes for AAP are related to the colder environment.

III. AAP CM-SM THERMAL CONTROL

Both passive and active thermal control methods are employed. Passive control, including the use of insulation, heaters,** selective optical coating, etc. is generally preferred because of the inherent simplicity and reliability. However, passive controls must be supplemented with the complicated but

* A requirements summary taken directly from the July 18, 1968 description is provided in the Appendix.

**Electric heaters are traditionally categorized as passive or semi-passive.

more versatile active controls including circulation fans, liquid circulation systems, and radiators. Although the use of passive controls usually means a savings in power and weight, an overly large use of electrical heaters may place excessive demands on the electrical power capabilities.

The thermal characteristics of the CM have remained essentially the same for AAP and Apollo, and its thermal control system is well defined at this stage of design. Certain aspects of the SM thermal control system are not as well defined. Although it has been decided to compensate for the colder AAP mission by the addition of heaters and insulation in the SM, details of size and placement are not yet complete. The thermal characteristics of the SM have been altered by changes in the location and size of various tanks and equipment stored. The changes must be incorporated in the analytical model before insulation and heater placement in the SM can be detailed. Since thermal design considerations and pending equipment changes are interrelated, additional changes to SM thermal control are possible. The current electrical power requirement for heaters is estimated at 900 watts for the coldest mission (Alternate AAP 3-4), which is reduced from the earlier estimate of 1,306 watts. (See Table II for a North American list of heater requirements.)

General CM-SM Structure

The CM consists of an outer shell of stainless steel honeycomb (heat shield) and an inner shell (pressure vessel) of aluminum honeycomb separated by a layer of fibrous silica insulation (Hitco Corp. TB 15,000). The insulation layer isolates the CM inner compartment housing the crew and electrical equipment from its environment; however, substantial heat leaks still occur at joints and windows.

The SM is basically a light weight structural support assembly for the propellant tanks, cryogenic storage tanks and EPS components. It reacts quickly to changes in temperature and is ineffective in smoothing temperature differences. (The SM outer shell temperatures range from -110°F to +250°F.) However, crinkled aluminized Mylar and Kapton insulation is employed to reduce unfavorable heat transfer. Insulation performance is a function of installation techniques and residual gas pressure. Venting is provided by random 1/8 inch diameter holes in each layer of insulation.

Except for entry when the CM and SM separate, the CM and SM are physically joined to form a unit - the CM-SM (see Figure 1). As a unit, they are exposed to similar thermal environments, however, heat transfer across their joining bulkhead is minimal due to the blanket insulation separating the two modules.

Ablative Layers

Much of the CM-SM exterior is covered with ablative layers to provide protection from aerothermodynamic loads. The nose and sides of the CM are covered with a boost protective cover that protects the CM and its coatings during launch and then is removed ("blown off" with the escape tower). A 0.3" cork layer on this cover serves as the ablator. In addition to the boost protective cover, the CM is covered with a layer of epoxy resin fiber ablator (AVCO CORP. 5026-39) for thermal control during entry.

The SM is covered with a cork layer except, primarily, for the radiators. This layer varies in thickness since it also serves to protect the SM during RCS firing events.

Aerothermodynamic heating during boost and entry is less in AAP than in Apollo, and Block II ablative coatings are generally adequate. The only exception is the SM cork pads. Maximum duration SM RCS firing events are 1,200 seconds for AAP versus only 500 seconds for Apollo. Direct heating from plume impingement will char substantially more of the cork layer. This requires thicker pads.

SM Aft Heat Shield

SPS firing produces high nozzle temperatures which lead to heating of the SM aft portion. The Block II aft heat shield, consisting of a nickel cover, silica fiber batting and layers of crinkled aluminized mylar superinsulation, is more than adequate for AAP if it is not required to serve for both positive and negative β angles. A coating change is needed to compensate for solar heating at negative β .

Surface Coatings

To minimize adverse radiant heat transfer, the CM-SM surface is covered with selective coatings, except for the radiators covering approximately half of the SM lateral surface, and the SM cork pads charred during launch and RCS firing events.

The Apollo coatings are not suited for the AAP fixed attitude environment. For the SM areas, an aluminum filled polyurethane paint with a solar absorptivity of 0.26 and an emissivity of 0.26 is chosen. In addition, a new metallic "plume/shadow shield" protects sun directed SM RCS components from overheating. For the CM surface, a coating system with solar absorptivity of 0.1 and an emissivity of 0.1 is tentatively selected.

A primary consideration in the choice of coatings is their resistance to degradation. Plume impingement during removal of the boost heat shield may limit the effectiveness of CM coatings, and surface heating during launch chars some of the SM cork layers. Ultra violet degradation during orbit is substantial for many coatings.

SM Components Thermal Control

Thermal control employed in the SM is passive, except for the EPS fuel cell coolant circuits. In general, the colder AAP fixed attitude missions plus various tank capacity and location changes have altered the placement of insulation and have required the addition of heaters. Heaters and insulation are sized for the cold AAP 3-4 alternate mission.

Cryogenic Tanks

Cryogenic tanks are heat sinks due to their low temperatures and large thermal capacities. They are thermally isolated by vacuum jacketing; however, they are supplied with heaters for pressurization purposes. During initial pressurization of the Orbital Assembly, O₂ and N₂ are heated for flow rates up to 20 lb/hr., and during Extravehicular Activity O₂ is heated for flow rates up to 20 lb/hr. (The use of waste heat for pressurization is discussed later.)

A study of heating requirements for O₂ and N₂ indicates that, instead of the 50°F to 70°F levels formerly listed, delivery temperatures down to 45°F are acceptable.

RCS and SPS Temperatures

SM RCS and SPS nozzles and engines are cooled radiantly when firing. This leads to excessive cooling when not firing. RCS propellant temperatures must be maintained between 40°F and 85°F, and RCS engine clusters must be maintained between 70°F and 134°F. SPS propellant cannot be allowed to reach temperatures less than 35°F. To prevent excessive cooling, and thus assure propulsion system restart, electric heaters are provided for fluid controlling components. Additional heaters are being added for the colder AAP environment (See Table II). (Thermal protection for RCS tanks located near sun-directed quads is provided by the plume/shadow shield.)

EPS Coolant Circuit

The three EPS fuel cells are cooled by a water-glycol (120 lb/hr maximum total flow rate) circuit connected to eight radiator panels (5 ft² each) located on the fairing between the CM and SM (Figure 1). These panels are isolated from the surrounding SM structure. Each cell has its own coolant circuit and self-contained pump (See Figure 2), but the radiators are used in common.

The Block II EPS coolant circuit apparently requires little modification for AAP, even though a new fuel cell power plant has been selected. However new maximum and minimum power output limitations are imposed on the fuel cell power plant. New analysis is planned.

Manually actuated valves bypass 3 of the 8 radiator panels for each fuel cell during low heat loads. Coolant liquid freezing is a potential problem when any cells are shut down completely; however, thermal coupling with the coolant loops of the cells that remain in operation prevents freezing. Further protection from freezing is attainable by continuing to pump coolant through a cell that has been shut down.

CM Components Thermal Control

CM Passive Control

Passive control inside the CM must be modified from Block II to compensate for the colder AAP environment. More insulation and heaters are needed for tanks and lines (waste water, potable water, and a few CM RCS components), and heaters are being considered for water venting lines and ports to prevent freeze-up.

ECS Coolant Circuit

CM thermal control depends primarily on the active coolant circuit. An ethylene-glycol and water mixture (62.5% to 37.5%) liquid coolant is pumped through various heat exchangers located in the CM and is delivered to radiators located in the SM, where waste heat is emitted to space (See Figures 3 and 4). There is a primary coolant circuit and, also, a secondary circuit to be used in emergency. Both circuits form complete, but separate, loops through the CM and SM. Two coolant circuit subsystems are generally recognized: (1) the "coolant circuit subsystem" consisting of all components (primary and secondary) located in the CM, and (2) the "radiator subsystem" consisting basically of all circuit components located in the SM. Although parts of this system are located in the SM, it provides active thermal control only for the CM cabin and equipment. The entire circuit is considered part of the CM Environment Control System (ECS).

Coolant Circuit Subsystem

The AAP coolant circuit subsystem hardware is essentially the same as Block II (See Fig. 3). In the primary coolant circuit, the water glycol mixture is driven at 200 lb/hr by a pump assembly (two pumps in parallel). This circuit removes heat from a water chiller, a pressure suit heat exchanger, and electronic equipment coldplate network, and either removes or adds heat to the cabin atmosphere. This atmosphere control is attained by selective routing of the coolant. During the cabin full-cooling mode, 167 lb/hr flows through the water chiller, the pressure suit heat exchanger, and the cabin heat exchanger, and then joins the remaining 33 lb/hr to pass through the coldplates. During the cabin full-heating mode, 167 lb/hr flows through the water chiller and the pressure suit heat exchanger and then joins the remaining 33 lb/hr to flow through the cold plates before all 200 lb/hr flows to the cabin heat exchanger. Since the major waste heat load is in the cold plates, the cabin temperature can be controlled up or down. (The CM heat exchanger is sized to control the CM atmosphere under the assumption that atmosphere exchange with the Multiple Docking Adapter is isothermal.)

An evaporator and a coolant reservoir are also included in the primary coolant circuit subsystem. The evaporator provides extra heat rejection capability to supplement the radiators by evaporating water (approximately 1,000 BTU/lb water). It is also used above 110,000 ft. during launch and entry where steam can be vented. (See Figure 3). The reservoir serves as a heat sink during launch, when the radiator subsystem is bypassed, and during entry. During prelaunch, temperature controlled coolant is externally circulated for ECS thermal control by the Ground Support Equipment.

The secondary loop in the ECS coolant circuit subsystem serves primarily as backup thermal control during emergency, and is not a complete redundancy of the primary loop. There is no secondary glycol reservoir, no connection to the potable water supply, and no capability to add coldplate waste heat to the cabin atmosphere through the heat exchanger. A separate pumping assembly (1 pump instead of two) and a secondary evaporator are included in the secondary loop.

The purpose served by the ECS secondary coolant loop is being examined for AAP. Although it is intended primarily for emergency control, other components may be able to serve the same function. For example, the water evaporator in the primary loop can remove waste heat during radiator failure.

The only significant baselined change to the Block II coolant circuit subsystem is the implementation of a two point coolant control. In the Block II system, coolant returning from the ECS radiator subsystem is automatically controlled at 45°F by either mixing with hot coolant to raise the temperature or by removing heat in the evaporator to lower the temperature. The automatic control is monitored with a temperature sensor on the coolant line. To compensate for the AAP colder environment, crew selection of two coolant control temperatures, 45°F and 60°F, is provided by the addition of a second temperature sensor (15°F higher). The 60°F coolant will result in reduced waste heat removal. This enables the maintenance of cabin temperatures without adding more heaters. This does not result in CM humidity problems since water and CO₂ are removed in the Airlock Module.

Radiator Subsystem

The ECS radiator subsystem (See Figure 4), located in the SM, is modified to allow selective freezing. This is required because heat rejection requirements for AAP are only 1,500 to 6,000 BTU/hr versus 4,940 to 8,570 BTU/hr for Apollo Block II. The two 8 ft² radiator panels are bypassed, leaving two 40 ft² panels, and an automatic isolation valve is added to restrict flow to only one of these remaining panels during low heat loads. The other radiator panel will be allowed to freeze up. When both panels are operating, an existing Block II proportioning valve system divides coolant flow between the panels to minimize outlet temperature differences.

Two heat exchangers added to the coolant line in the SM heat oxygen and nitrogen during high flow pressurization of the Orbital Assembly. An existing inline heater (500 watts) supplements waste heat if necessary. Normally, this heater serves to prevent coolant freezing. A new heater, identical to the first, is being added between the N₂ heat exchanger and the proportioning valves to provide further protection from radiator freeze-up.

The radiator subsystem is still subject to study. The proportioning valve system may not be needed since one 40 ft² panel with, perhaps, one 8 ft² panel may be sufficient to reject the maximum heat loads.

The secondary loop in the radiator subsystem simply connects the CM coolant subsystem to the radiators. It does not have a proportioning valve system and it bypasses the oxygen and nitrogen heat exchangers. It is provided, however, with an inline electric heater to prevent coolant freezing. As mentioned, the secondary loop may not be needed.

George M. Yanizeski

G. M. Yanizeski

1022-GMY-mef

Attachments

Figures 1-4

Tables I-II

Appendix

References

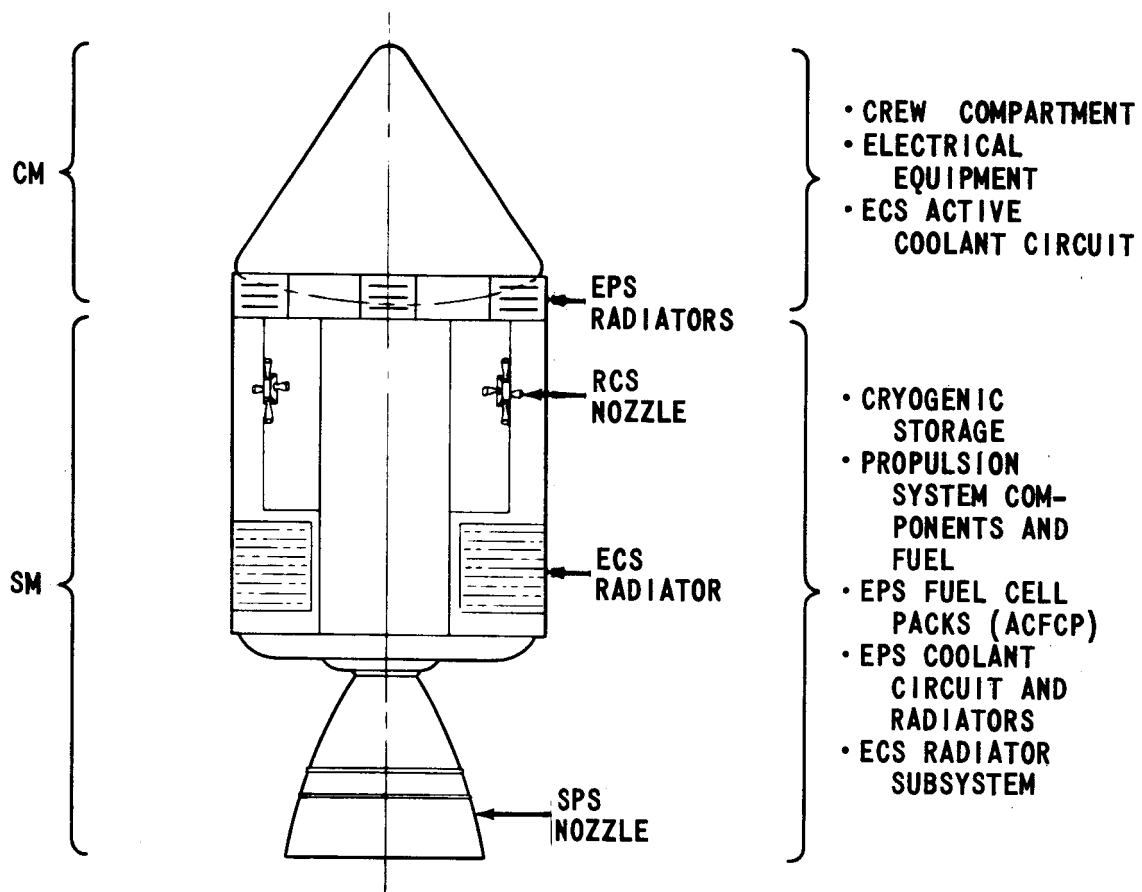


FIGURE 1 - CM-SM CONFIGURATION

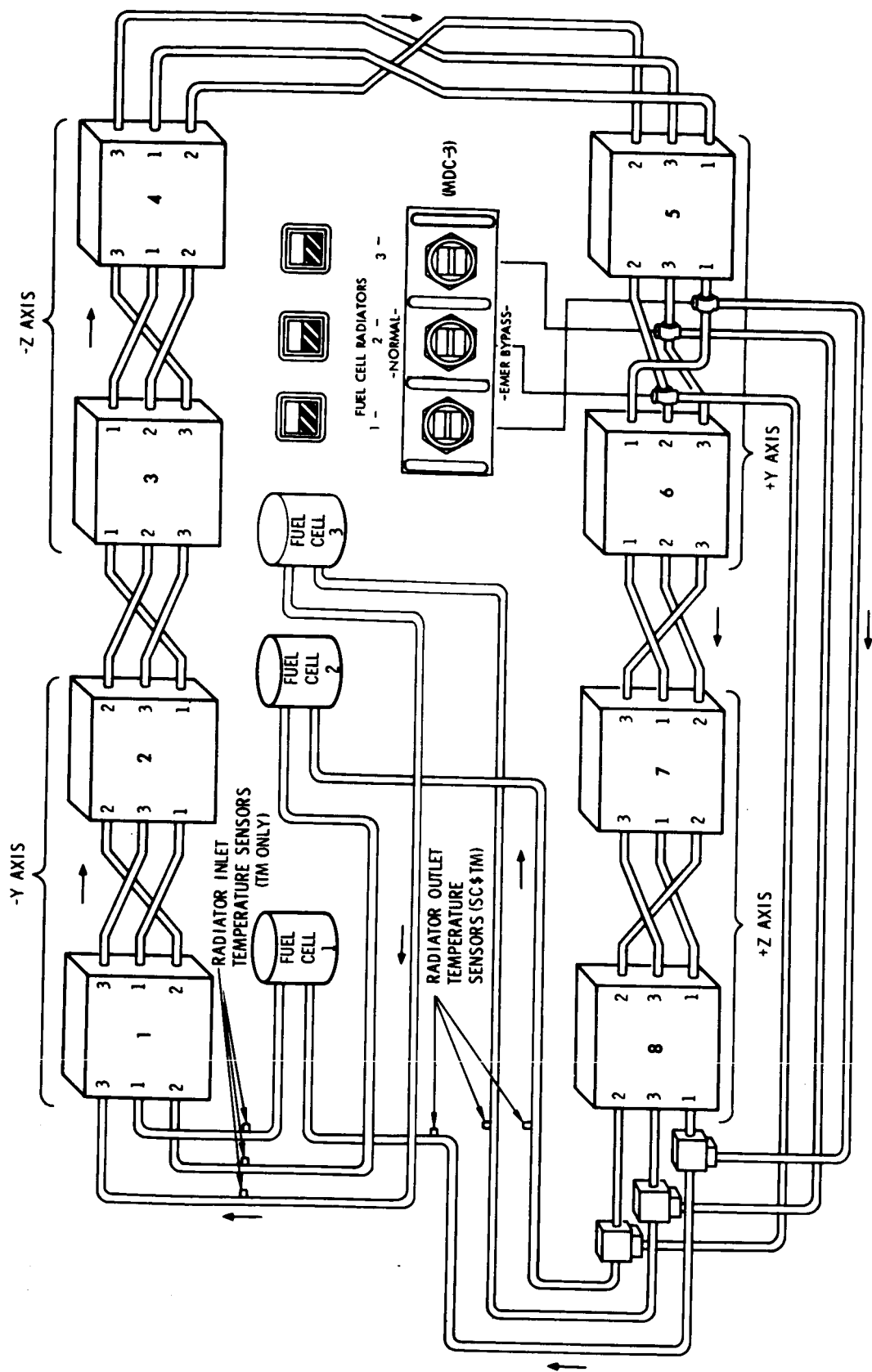


FIGURE 2 - BLOCK 11 EPS RADIATOR CIRCUIT (REF. 10)

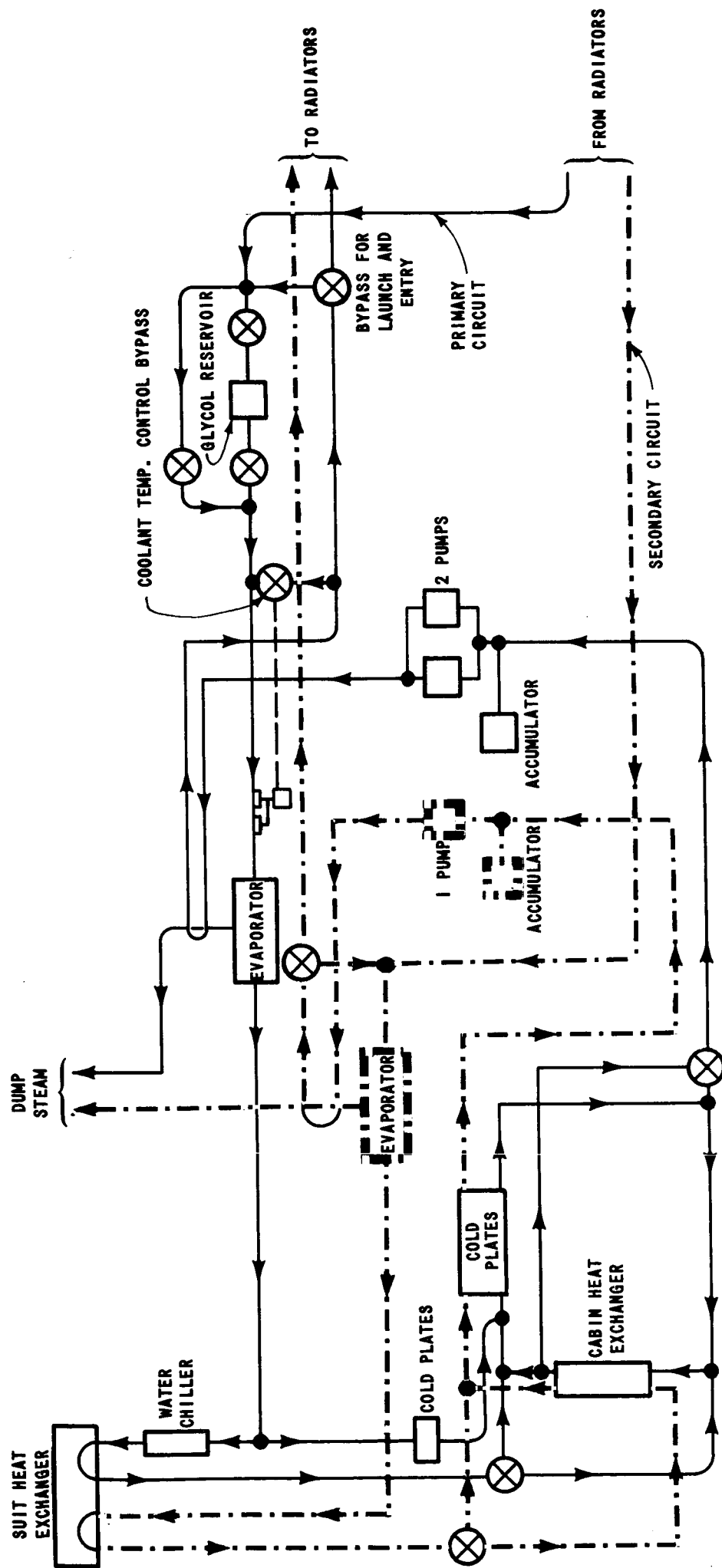


FIGURE 3 - ECS COOLANT CIRCUIT SUBSYSTEM

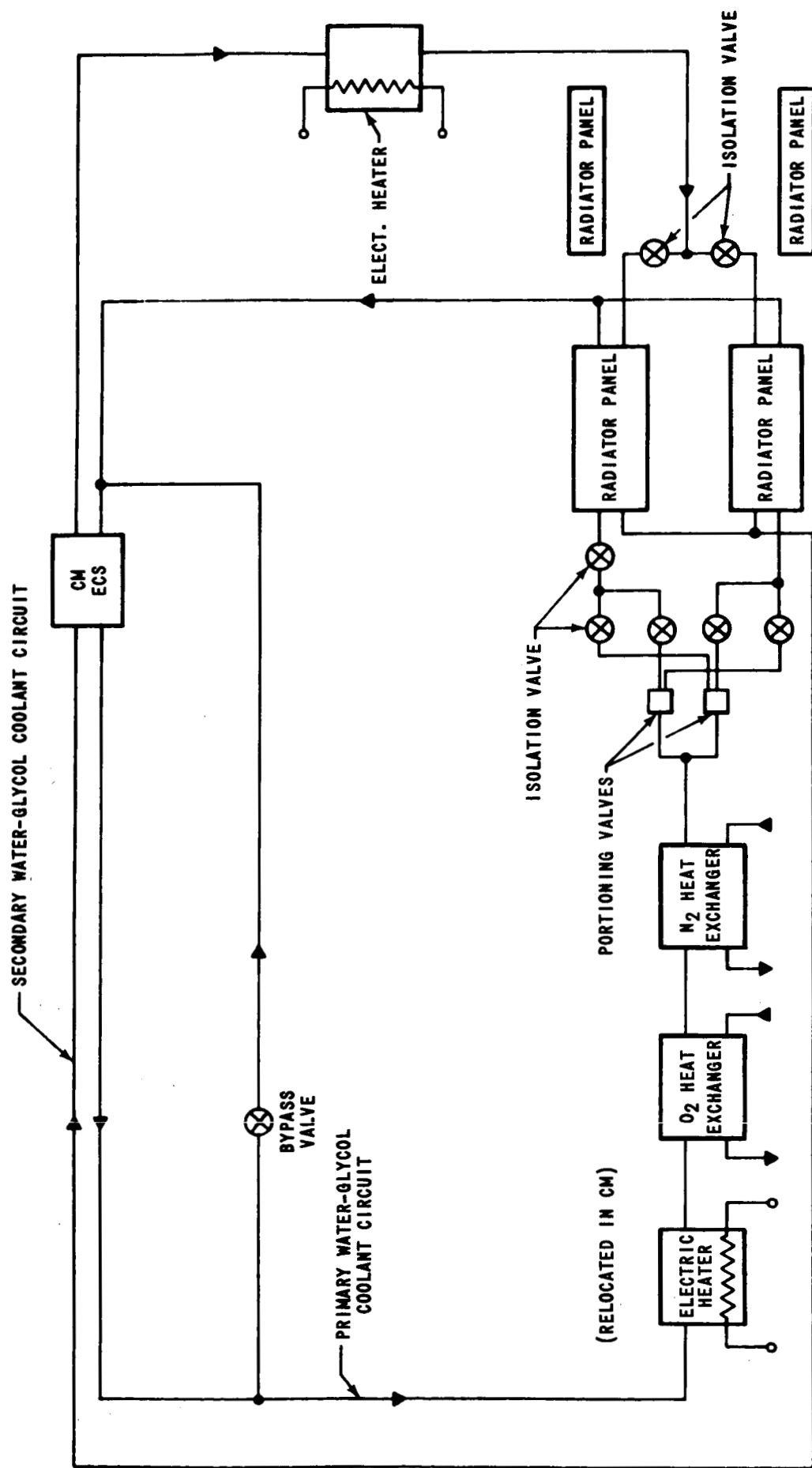


FIGURE 4 - MODIFIED AAP-ECS RADIATOR CIRCUIT (REF. 1)

BELLCOMM, INC.

Table I

Summary of Changes to Thermal Control

The NASA baselined changes related to thermal control are described in items 1 to 9. An additional listing of North American baselined changes are included because they reflect current contractor thinking and include more detail. Except for items 2 and 5, items 1 through 9 are basically common to both baselines.

<u>Item No.</u>	<u>Change</u>	<u>Reference</u>
1	Replumb ECS radiator system to bypass series (small) panels and to permit isolation of one stagnation (large) panel	NASA Manned Spacecraft Center Document "AAP Standard CSM Configuration" prepared by the General Electric Co. July 19, 1968
2	Relocate in CM inline heaters for ECS radiator	"
3	Modify controls for CM coolant bypass valve to provide crew selection capability for either of the two coolant control temperatures	"
4	Add water heaters (CM)	"
5	Add valves and controls to permit radiator panel isolation	"
6	Add N ₂ and O ₂ heat exchanger to present liquid loop to satisfy increased flow augmented with electric heaters	"
7	Modify RCS "thruster cluster" heater control loop	"

Item No.	Change	Reference
8	Add insulation, heaters and associated controls and displays on all RCS tanks and lines (SM)	NASA Manned Spacecraft Center Document "AAP Standard CSM Configuration" prepared by the General Electric Co. July 19, 1968
9	Add heaters as required to SPS lines, tanks, engine, components	"
10	Modify CM coating subsystem optical properties	Doc. No. SD 68-555 "Apollo Applications Program CSM Configuration Baseline" Gould, C. L. (North American Rockwell) July 23, 1968, Revised October 1, 1968
11	Modify SM superinsulation blankets tailored to AAP subsystem configuration	"
12	Modify SPS feedline heaters and controls	"
13	Add CM RCS tank heaters/insulation	"
14	Add CM ECS tank heaters/insulation	"
15	Add SM RCS panel shadow shield	"
16	Remove SM cork over RCS panels	"
17	Add SM EPS return battery pack heaters	"
18	Modify SM RCS Quad heater control	"
19	Add SM superinsulation blankets in Bays II and V	"

BELLCOMM, INC.

Table II

Heater Requirements Summary
(North American - Rep. No. SD 68-555, pp. 85-86)

Electric Heaters*

Location	Size (Watts)	Number
<u>CM</u>		
CM RCS		
Engines	**	**
Helium tanks	7.82	2
Oxidizer tanks	11.75	2
Fuel tanks	6.27	2
ECS		
Potable-water tank	9.4	1
Waste-water tank	18.8	1
<u>SM</u>		
SM RCS		
Engine quads	72.0	4
Primary	72.0	4
Secondary	72.0	4
Propellant tanks	39.2	16
Helium tanks	22.1	4
Helium pressurization panels and lines	26.2	4
Supplementary tank shelves	63.3	2
SPS		
Propellant tanks	255.3	2
Helium pressurization panel	14.0	1
Feedlines and valve system	105.2	1
EPS		
Return battery pack	50.0	1

* Black line at right indicates valves different from Block II.

**Heating is provided by energizing the 50-watt direct coil on each engine solenoid valve.

BELLCOMM. INC.

Appendix

Requirements Summary from SD-68-551*

The following paragraphs, taken directly from SD 68-551, summarize the basic AAP CM-SM thermal control requirements. Paragraph numbers are those appearing in SD 68-551 (pp. 2-41 to 2-62). A vertical line in the right margin indicates a system requirement peculiar to AAP. These lines are part of the original text. Review Item Discrepancies from the CM-SM Preliminary Requirements Review have been incorporated.

2.2.1.1.2.1 Fuel Cell Powerplant Subsystem. The fuel powerplant subsystem shall provide the following:

3. Fuel Cell Cooling - A radiator system shall provide for the rejection of waste heat generated by three fuel cells (F/C) to space.

Eight curved panels shall comprise the radiator assembly. Each panel shall have a fixed radiating area of uniform thickness. The radiator panels shall be located on the outer periphery of the CM/SM fairing. Three independently operating fluid loops shall be equally spaced on each panel with associated extended surfaces (fins). Each loop position shall be alternated from panel to panel. The fluid loops shall be manifolded in series.

Each radiator panel shall -

- a. Be thermally isolated from spacecraft environmental conductive effects.
- b. Exhibit optical properties as follows:

Solar absorptance, $A_s = 0.20$

Hemispherical emittance, $e_H = 0.92$

The radiator area shall be 40 ft^2 , $5 \text{ ft}^2/\text{panel}$.

* SD 68-551 "Apollo Applications Program CSM Mission/System Requirements," North American Rockwell Corporation, July 18, 1968.

Total radiator area reduction to 25 ft² shall be made possible by the incorporation of a radiator bypass line for each fluid loop. Three of the eight panels shall be capable of being removed from service by the bypass. The coolant fluid (water/glycol) of the radiator assembly shall collect the waste heat from the fuel cell power plant at the condenser. This fluid shall preheat the fuel cell reactants and the returning coolant fluid before entering the first radiator panel. The radiator heat shall be transferred convectively from the fluid to the panel ducts and fins then radiated to space.

Fuel cell radiator heat-rejection capability for a nominal profile shall be 1,718 to 6,796 Btu/hr at the following conditions:

- a. AAP 3-4, 0-degree B-angle with direct solar irradiation
 - b. AAP 3-4 backup, 53-degree B-angle with no direct solar irradiation.
4. Fuel Cell Venting - The three fuel cells shall produce a minimum of 2900 watts of dc power without requiring the use of steam venting for disposing of excess heat. An overboard vent capability shall be required that will not freeze. With one fuel cell out, the remaining two shall produce a minimum of 2500 watts without venting. With two fuel cells out, the remaining fuel cell shall produce a minimum of 1250 watts without venting.
 5. Water Production - The fuel cells shall produce potable water in accordance with the requirements of 2.2.1.1.1.4 and 2.2.1.3.3.3.
 6. Location - The fuel cell powerplant subsystem shall be located in the SM.

2.2.1.3.2 Thermal Control of Habitable Areas Subsystem.

The thermal control of habitable areas subsystem shall remove excess heat generated by the crew and CSM equipment and reject it to space.

2.2.1.3.2.1 Subsystem Requirements. The thermal control subsystem shall meet the following requirements:

1. Active thermal control for CM equipment and atmosphere shall be provided throughout the mission.
2. The thermal control system shall be redundant for critical equipment and provide for emergency cooling during aborts in the event the primary cooling system should fail.
3. A radiator system shall be utilized to reject the waste heat to space.
4. The coolant shall not be permitted to freeze except in one section at a time in a parallel radiator system.

2.2.1.3.2.2 Performance Requirements. The active thermal control subsystem shall have the following performance requirements:

1. The subsystem shall provide thermal control for equipment. No critical equipment shall depend upon the cabin atmosphere for cooling and pressurization.
2. The subsystem shall provide for controlling cabin atmosphere temperature to the limits defined in paragraph 2.2.1.3.1.1.2.*
3. The ECS radiator system shall be capable of rejecting waste heat at rates varying from 2,000 to 6,500 Btu/hr. During initial OA pressurization, the ECS radiator system shall heat O₂ or N₂, flowing at a rate of 10 lb/hr, from cryogenic storage temperatures to 50 to 70F. During EVA or MDA surge tank refill periods, O₂ flowing at a rate of 15 lb/hr shall be heated from cryogenic storage temperatures to 50 to 70F.

2.2.1.3.6 CSM Thermal Control

The CSM shall be maintained within its acceptable temperature limits regardless of vehicle orientation for either the primary or backup mission.

2.2.1.3.6.1 Subsystem Requirements. The CSM thermal control subsystem shall:

* Paragraph 2.2.1.3.1.1.2 gives the CM atmosphere temperature requirement as normal 75±5F; emergency temperature depending on prevailing relative humidity. In RID 4-23 dated 7/24/68, "75±5F" was removed and "NASA comfort criteria" inserted.

1. Provide the necessary insulation and coatings for ascent, orbit, rendezvous, docking, docked, and entry.
2. Provide for temperature control of all components, tanks, lines, structure, etc., in the unpressurized areas of the CSM (temperature control of habitable areas is discussed in 2.2.1.3.2)
3. Whenever electrical heaters are utilized, the heater and control characteristics shall be such that large surges in power requirements and cycling are minimized. Heaters shall be redundant or multiple elements such that failure of one element shall not prevent providing proper thermal control.

BELLCOMM, INC.

References

1. NASA Manned Spacecraft Center Document "AAP Standard CSM Configuration," prepared by the General Electric Company, July 19, 1968.
2. SD-68-555, "Apollo Applications Program CSM Configuration Baseline," Space Division, North American Rockwell Corporation, July 23, 1968. Revised October 1, 1968.
3. PR-34-80, "Final Report for C & SM Modification Study," Martin Marietta Corporation, June 6, 1968.
4. G-317, "Final Report AAP CSM Modification Program Study," McDonnell Astronautics Company, June 6, 1968.
5. SD-68-551, "Apollo Applications Program CSM Mission/System Requirements," Space Division, North American Rockwell Corporation, July 18, 1968.
6. SID-67-54-1, "Apollo Applications Program CSM Study for Apollo Applications Bimonthly Summary Report," Vol. 1, North American Aviation, Inc., March 1, 1967.
7. AX-68-19, "Apollo Applications Program Electrical Power System," (view graphs). Space Division, North American Rockwell Corporation, September 1968.
8. AX-68-10, "AAP Thermal Control," (List of view graphs), Space Division, North American Rockwell Corporation, April 1968.
9. SID-66-1508, "Apollo Operations Handbook, Block II Spacecraft, Vol. 1, Spacecraft Description," Manned Spacecraft Center, March 1, 1967.
10. North American Briefing Charts, "Apollo Application Program Electrical Power System," September 1968, Manned Spacecraft Center, Houston, Texas.

BELLCOMM, INC.

Subject: AAP CM-SM Thermal
Control Systems

From: G. M. Yanizeski

Distribution List

NASA Headquarters

Messrs. E. P. Andrews/MLA	T. A. Hanes/MLA
O. T. Bumgardner/MLT	T. A. Keegan/MA-2
H. Cohen/MLR	H. T. Luskin/ML
P. E. Culbertson/MLA	H. Mannheimer/MLA
J. H. Disher/MLD	J. Marsh/MLT
G. A. D'Onofrio/MLT	C. P. Mook/RV-1
J. A. Edwards/MLO	M. Savage/MLT
L. K. Fero/MLV	R. E. Storm/MLR
J. P. Field, Jr./MLP	

MSC

Messrs. R. G. Brown/ES-16	H. W. Dotts/KS
E. T. Chimenti/ES-5	R. L. Dotts/ES-5
C. N. Crews/KS	R. L. Frost/KS
R. B. Davidson/KF	H. E. Gartrell/KF

MSFC

Messrs. R. R. Fisher/R-P&VE-PTP	W. O. Randolph/R-P&VE-PTE
G. Hardy/R-SE-A	H. Trucks/R-P&VE-PTP
G. D. Hopson/R-P&VE-PT	J. L. Vaniman/R-P&VE-PTP

North American Rockwell

Messrs. C. F. Lindley
A. Nusenow

Bellcomm

Messrs. A. P. Boysen	J. Z. Menard
T. A. Bottomley	I. M. Ross
D. A. Chisholm	J. A. Saxton
S. S. Fineblum	P. F. Sennewald
D. R. Hagner	J. W. Timko
A. S. Haron	R. L. Wagner
B. T. Howard	

Div. 101 Supervision
Dept. 2015, 2034 Supervision
All Members Dept. 1021, 1022, 1024, 1025
Department 1024 File
Central File
Library